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APPLICABILITY OF FACILITY LAYOUT AND MATERIALS HANDLING MANAGEMENT FOR OPERATIONAL PERFORMANCE OF MANUFACTURING COMPANIES IN NIGERIA: A CASE STUDY

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ABSTRACT

This study examined the application of facility layout and materials handling management for operational performance as case study of a manufacturing company. Three specific objectives were established and data were collected from respondents using an open-ended question survey. The findings revealed that facility layout improves operational performance of production lines, decreases bottleneck rate, minimizes materials handling cost, reduces idle time, increases the efficiency and utilization of labour, equipment and space. Therefore, concluded that facility layout redesign and materials handling management resulted in significant reduction of the following indicators: amount of total workflow, material handling cost, total travel distance of goods, space used for assembly, number of workers, labor cost of workers and the number of stops. We recommended organizations should strictly adhere to management policy on facility layout and computerize their materials management system in line with the global changes for ease to track the movement of materials in the store.

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1. INTRODUCTION

In recent developments market globalization, every organization seeks efficiency in the production of goods and services which depends to a great extent on the optimum utilization of the scarce resources such as materials, machine, money and manpower in their right proportions. Nevertheless, as organizations strive to meet set objectives and the rising demands of customers, there is need for continuous better operational performance in production runs and handling of materials. Amidst the growing market globalization, where customer demands are changing continuously, companies have to improve performance by focusing on cost minimization and profit maximization for increased competitiveness. Therefore, the application of facility layout and materials handling management in companies is keen for this study.

Facility layout design is one of the most important and frequently used performance improvement methods because, it significantly reduces operational costs of companies. As manufacturing companies and service providers expand and become more complex, manufacturing systems tendto be agile and flexible in order to respond to the rapidly changing economic environment. Therefore, facility layout design means the process of finding an optimum arrangement of facilities(department, workstation, machine, equipment) in the organization (Sukanto, 2002). The objectives of facility layout design are to improve the performance of the production processes, minimize the total layout design and increase competitiveness. An efficient layout contributes to the reduction in the production cycles, work-in-progress, idle times, number of bottlenecks or material handling times and increases production output with obvious implications on productivity.

The overall performance of an industrial firm is significantly affected by the design of its manufacturing facility. It may be a machine tool, a work centre, a department, a machine cell, a manufacturing cell or a warehouse. A plant layout is an arrangement of everything needed for production of goods or delivery of services. A well–designed plant layout results in efficient material handling, less transportation time, and short path (Fazlollahtabar & Saidi-Mehrabad, 2015). This in turn, leads to low working-process levels, effective production management, decreased cycle times and manufacturing inventory cost, improved on-time delivery performance, and consequently, higher product quality. The efficiency of a layout is typically measured in termsof material handling (transportation) cost. The material handling costs are directly influenced by the distances a unit load must travel.

Materials handling management is among many factors that contribute to improving a company's performance. The Materials Handling Industry of America (MHIA) defines materials handling management as "the movement, storage, control and protection of material, goods, and products throughout the process of manufacturing, distribution, consumption and disposal". The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions. Then it is observed that handling is broader than simple materials movement, although both terms are sometimes used interchangeably.

This study identified that among other measures to improve operational performance, it would be necessary to focus on materials handling management in the manufacturing process through reduction of delays in forklifts services, handling and transportation which most times result in excessive setup time leading to production delays.

Aim and Objectives

The aim of this study was the application of facility layout and materials handling management for operational performance.

To achieve this, the following specific objectives were established: (i) to describe the changes in material handling processes at the company; (ii) to evaluate internal material handling flow in manufacturing, verifying the improvements; and (iii) to analyze internal customers' satisfaction levels relative to the new system.

2. LITERATURE

REVIEW2.1:

MATERIAL FLOW

Materials handling makes production flow possible, as it gives dynamism to static elements such as materials, products, equipment, layout and human resources (Stock & Lambert, 2001; Chopra & Meindl, 2001). Groover (2001) highlights that despite its importance, materials handling is a topic that frequently is treated superficially by manufacturing companies. However, other authors have perceived its relevance. During the period in which Shingo (1996) contributed to the development of the Toyota Production System (TPS), he developed the Production Function Mechanism that proposes to explain how the production phenomenon happens.

Shingo (1996) indicated that, in the West, production was treated as a process of a sequence of operations. In the Production Function Mechanism, the concepts are directly related to a production analysis focus. A process analysis consists of an observation of the production flows that turn raw materials into final products. From this concept, the author highlights that the main analysis is the one associated with the process, because it follows the production object. The analysis of the operations comes later because it focuses on production subjects (operators and machines). When making this distinction, it is possible to perceive the relevance of materials handling.

Beyond the basic function of movement, it is also relevant to cite the functions of storage and information transfer, which occurs simultaneously and has both strategic and operational dimensions. Organizations are relying on information systems using tools like Electronic Data Interchange (EDI), or similar information technology resources, to gain in precision and reliability,in the interchange, and availability of information (Stock & Lambert, 2001; Laudon & Laudon, 2006; Milan, Basso & Pretto, 2007).

According to Asef-Vaziri & Laporte (2005) an important proportion of manufacturing expenses can be attributed to material handling and the most critical material handling decisions in this area are the arrangement and design of material flow patterns. This idea is shared by Ioannou (2002), which argues that an important aspect of any production system is the design of a material handling system (MHS) which integrates the production operations.

The relevance also occurs in another context. Ballou (1993) states that the storage and handling of goods are essential among the set of logistics activities, and their costs can absorb 12% to 40% of its costs. In addition, the MHIA estimates that "20% to 25% of manufacturing costs are associated to handling" (Groover, 2001, p. 281). According to Yannopoulos, Elias & Attahiru (1994); Borges, Pasa, Borsa, Milan & Pandolfo (2011), material handling accounts for 30–75% of the total cost of a product along the production chain, and efficient material handling can be responsible for reducing the manufacturing system operations cost by 15–30%.

For Bowersox, Closs & Helferich (1996), the main logistic responsibility in manufacturing is to formulate a master-program for the timely provision of materials, components and work-in- process. Stevenson (2001) understands that logistics (including materials and goods flowing in and out of a production facility as well as its internal handling) has become very important to an organization to acquire competitive advantages, as the companies struggle to deliver the right product at the right place and time. The main challenge is to promote, with low cost, a flow whose velocity allows the execution of manufacturing process with the expected satisfaction level.

: ELEMENTS AND CHARACTERISTICS OF A MATERIAL HANDLING SYSTEM

Materials handling study requires that several elements are considered. The first is a handling system project, which covers activities of sequencing, velocity, layout and routing (Groover, 2001). In order to complete the analysis, Groover (2001) recommends analyzing the material itself (or object) to be transported. Therefore, it suggests the classification of Muther and Hagan (cited in Groover, 2001), which considers: (i) physical state (solid, liquid, gas); (ii) size (volume, length, width, height); (iii) weight; (iv) condition (hot, cold, dry, dirty, sticky, adhesive); (v) risk of damage (weak or strong); and (vi) safety hazards (explosive, flammable, toxic, corrosive, etc.).

Additionally, the issue of equipment and devices must be examined. Dias & Quaglino (1993) adopts the term "moving" to describe what, in this article, is called management (handling) to adopt the terminology of Groover (2001). When dealing with equipment, Dias (1993) presents a broad classification that covers five categories: (i) transporters (belts, chains, rollers, etc.); (ii) cranes, hoists and lifts; (iii) industrial vehicles (carts, tractors, pallet transporters, forklifts); (iv) positioning equipment, weighing and control (ramps, transfer equipment); and (v) stents and support structures (pallets, holders, reels).

According to Chan, Qi, Chan, Lau & Ip (2003), a key factor in material handling system design process is the selection and configuration of equipment for material transportation. This is directly related to this study.

According to Gurgel & Schlick (1996), the equipment should be selected based on some preliminary considerations: take into account the utilization of the factory floor and its load capacity; examine the dimensions of doors and corridors; pay close attention to ceiling height, identify the environmental conditions and their nature, avoid the use of combustion engines traction equipments in storage of food products, meet all safety standards to protect humans and to eliminate the possibility of incurring criminal and civil liabilities arising from accidents, and examine all kinds of available energy options and their capacity to supply required movements.

The right choice of equipment and location of work-in-process is fundamental for the optimization of a company's manufacturing capacity. Bowersox, Closs & Helferich (1996) state that a critical factor in positioning stocks in process is a balance between convenience and consolidation to create efficiencies when the stock flows along the value chain.

The importance of layout, which defines the placement of equipment and, consequently, restricts possible routes and sequencing, can be perceived by the prominence that the subject is treated in production management literature. The analysis of the relationship between layout studies and material handling, however, does not receive much attention in the same literature. This lack of attention can be seen in works like Gaither and Frazier (2002), Chase, Jacobs and Aquilano (2006) and Slack, Chambers, Harland, Harrison and Johnston (1997).

Finally, the systems and information technology constitute essential factors for materials handling management. Stair and Reynolds (2006), Laudon and Laudon (2006) and O'Brien and Marakas (2007) support the study of fundamentals and general principles of information systems.

In order to improve the performance of distribution operations and, in this specific case, the internal material handling process, it is important to consider both human and technical factors (Chakravorty, 2008). In this sense, this study assesses the internal customers' perception of a material handling process improvement.

With regard to the attributes to be considered in a material handling system, according to Kulak (2005), effective use of labour, providing system flexibility, increasing productivity, decreasing lead times and costs are some of the most important factors influencing selection of material handling equipment. These factors are directly related to some attributes found in the present study.

The determination of a material handling system involves both the selection of suitable material handling equipment and the assignment of material handling operations to each individual piece of equipment (Sujono & Lashkari, 2007). Hence, according to Sujono & Lashkari (2007) material handling system selection can be defined as the selection of material handling equipment to perform material handling operations within a working area considering all aspects of the products to be handled. In this context it is important to mention that, in this study, only the selection of the material handling equipment was considered.

: PROBLEM AND INTERVENTION DESCRIPTION

The first sub-section describes the situation prior to the intervention, identifying the problems that were found. The second describes the factors that motivated the change. The third describes the changes and the situation after its completion. Besides variables and sub-variables, customers' overall satisfaction regarding the implemented changes was also evaluated.

: SITUATION PRIOR TO THE INTERVENTION

This study was conducted in the manufacturing sector of an air conditioner company. The manufacturing sector is responsible for almost all of the supply of assembly lines, including the components that go through a pre-assembly process before proceeding to final product assembly. In this sector are concentrated cutting and bending tools and dies required for components manufacturing to assembly lines. The whole process runs with the aid of forklifts. Often, the setup time is equal to or higher than the time needed for parts manufacturing. This situation, coupled with the cost of downtime, demonstrates the importance of the tooling exchange process.

Besides helping in the execution of setups and carrying out internal transport managed by an electronic scoreboard installed in the factory roof, forklifts also performed activities for transporting materials between pavilions. When executing this last activity, the forklifts often travelled on uneven roads, which caused great bouncing, burdening maintenance cost for equipment wear or premature breakage.

Often, when a forklift leaves its workplace to transport a container between pavilions, delays in machines' setups are generated, causing unnecessary costs and stress on the forklift operator. The operator could do little besides feel forced to increase the speed during the route, creating risks of accidents with personal injury and/or materials damage. This activity as well as the studied process relate to Goldratt's Theory of Constraints (TOC) to seek bottlenecks and reduce or eliminate them (Goldratt & Cox, 2004).

Although there were enough forklifts to meet the demand from the manufacturing sector, many times it was not possible to meet immediately the manufacturing needs due to reasons like long distances to travel and frequent maintenance due to excessive use of the equipment. This directly affected internal customers' satisfaction.

: CHANGE MOTIVATORS

Due to development of new markets, manufacturing demands for a large variety of components and final product assemblies increased. This demand growth led to speed increases and changes in how materials and tools were being handled and transported in order to monitor manufacturing requirements.

With these changes and demands for manufacturing to attain the company's goals, there was also pressure for growth and lack of tolerance with forklift operators, since the work did not always run quickly and with quality. Additionally, forklift maintenance costs were increasing, demanding sometimes excessive spending that jeopardized the budget. The dissatisfaction and demotivation of forklift operators was notorious, and an increase was also noticed in the number of collisions between the equipment. Finally, boxes and containers were unsatisfactorily stored in the hallways together with the machines to attempt to reduce production interruptions.

: THE CHANGES AND THE SITUATION AFTER THE IMPLEMENTATION

One suggested solution was to rent two forklifts as a way to solve the problem. But this only served to soften it, and brought a larger cost to the company. It was realized then that it was not the quantity of equipments that was going to solve the problem but the way material handling was being executed in relation to the necessity of the presented changes.

From this observation, processes and material flows were mapped and separated in two ways: (i) vertical movements which make greater efforts and little ground movement; and (ii) horizontal movements that rely on traction to travel longer distances, including transport out of the work units.

Another proposed solution was to use a tractor towing small "wagons", forming a kind of train. Ballou (1993) states that this approach is more economical for larger volumes that must be moved over long distances along the same route.

Several cargo (pallets) units were constructed with special wheels, fitted with suspension coupled to support the material weight and traverse the gaps between the pavilions. Afterwards, several "cages" were made to be used for holding the parts that go through the processes of bath and painting. More robust containers for heavier and less delicate parts storage were also constructed.

The next step was to create spaces (pit stops) for pallets with their mobile parts on each workstation. In order to the truck driver to know when he could transport material, it was necessary to create an identification system. It was decided that every time that the operator finished the process in his station, he would put on the packaging a green sign indicating that the container would be ready to be transported to the next production step. The truck driver, when removing a filled container, should replace it with an empty one in the vacant post.

Tests were conducted with a timetable for the train passage, but this alternative did not meet the need for flexibility in case of emergencies (pieces to technical assistance and replacement of damaged materials in the assembly process).

It was then decided to set a path that would follow the manufacturing process sequence. To inform the train operator of some urgency, a mobile phone was given to him. Thus, the supervisor could communicate with the operator instantly when there were critical parts and / or components to be collected.

: WAREHOUSE STRATEGIES

The warehouse implements a First-In-First-Out (FIFO) approach for the flow of goods out of the warehouse. The main issue to consider with this strategy is that products have a certain shelf and products are released according to their DOM (date of manufacture) dates. The FIFO system induces double handling under the current system because new stock cannot be stacked on top of existing stock in the bin. The company employs the Julian Calendar System which displays on the packaging the DOM date, year produced, line number and the exact time the product moved off the production line. Reverse logistics is another strategy employed in the warehouse. Returned bottles are warehoused until pulled by demand to the production plant where they are used to fill new orders. It is important to consider space for this activity when planning the facilities design.

3: METHODOLOGY

: COMPANY CHARACTERIZATION

This manufacturing company is divided into four business units: (i) Air Conditioners; (ii) Fridges;

(iii) Television; and (iv) Sound Systems, and maintains a technology transfer contract with a renowned firm.

: DATA COLLECTION METHOD

The sample was the people directly involved with the daily flow of materials, selected intentionally. The respondents held positions as leaders, supervisors, forklift drivers and warehouse operators, enabling a comprehensive view of the problem. Data collection for the satisfaction survey was an open-ended question survey. Respondents were asked about their perceptions regarding the changes in materials handling emphasizing evidence of the improvements, problems still identified after change implementation and suggestions for the relevant attributes in question.

: DATA ANALYSIS

Table 1: Existing Plant Layout Material Flow

NO	DEPARTMENT FROM - TO	DISTANCE IN METER Mi	NO OF MOVES PER DAY Di	TOTAL DISTANCE TRAVELLED PER DAY IN METER Mi X Di
1	A-B	14	17	238
2	B-C	23	69	1587
3	B-D	46	48	2208
4	C-E	24	53	1272
5	D-F	18	29	522

6	E-F	24	37	888
7	E-G	14	43	602
8	F-G	25	42	1050
9	G-H	41	48	1968
10	H-I	23	63	1449
11	I-J	19	72	1368
12	J-K	24	47	1128
13	K-L	21	54	1134
14	L-M	57	39	2223
15	M-N1	45	38	1710
16	M-N2	62	28	1736
17	N1-O	95	55	5225
18	N2-O	75	35	2625
19	O-P	38	66	2508
20	P-Q	53	88	4664
21	P-A	85	46	3910
			ΣMiDi	**40,015**

Source: Research Survey (2023)

Table 2: Proposed Plant Layout Material Flow

NO	**DEPARTMENT FROM – TO**	**DISTANCE IN METER Mi**	**NO OF MOVES PER DAY Di**	**TOTAL DISTANCE TRAVELLED PER DAY IN METER Mi X Di**
1	A-B	8	10	80
2	B-C	12	24	288
3	B-D	23	18	414
4	C-E	15	33	495
5	D-F	9	19	171
6	E-F	12	13	156
7	E-G	9	28	252

8	F-G	14	21	294
9	G-H	21	17	357
10	H-I	10	32	320
11	I-J	9	22	198
12	J-K	8	29	232
13	K-L	11	36	396
14	L-M	36	24	864
15	M-N1	28	38	1064
16	M-N2	33	23	759
17	N1-O	49	33	1617
18	N2-O	40	39	1560
19	O-P	21	47	987
20	P-Q	37	39	1443
21	P-A	46	22	1012
ΣMiDi				**12,959**

Source: Research Survey (2023)

Calculation of Material Handling Cost

1. **Existing plant layout design**
   a. **Total distance travelled by various departments per day**

Σ Distance Mi (meter) x Number of moves per day (Di)

= ΣMiDi

= 40,015m/day

= 40,015m/day/3 shift = **13,338.33m/shift per day**

a. **Average material handling cost/meter**
= (Wages of worker per shift) / Average distance travelled per shift per day

= No. of worker salary of one worker per day/ Average distance travelled per shift per day

= 1 x (10,000/30) / 13,338.33

= NGN. 0.025 / meter.

b. Total material handling cost per day (Including all three shifts)

= Total distance in meter x Average material handling cost per meter

= 40,015 x NGN. 0.025

= **NGN 1,000.375 per day**

2. For proposed plant layout design

a. Total distance travelled by various departments per day

Σ Distance Mi (meter) x Number of moves per day (Di)

= ΣMiDi

= 12,959m/day

= 12,959m/day⁄3shift = **4,319.67/shift per day**

a. Total material handling cost per day (Including all three shifts)

= Total distance in meter x Average material handling cost per meter
= 12,959.67 x NGN. 0.025
= **NGN 323.99 per day**

b. Percentage reduction in transportation length

= (Difference in material movement /current material movement) *100%
= (13,338.33 − 4,319.67)/17,658 * 100
=**51.12%**

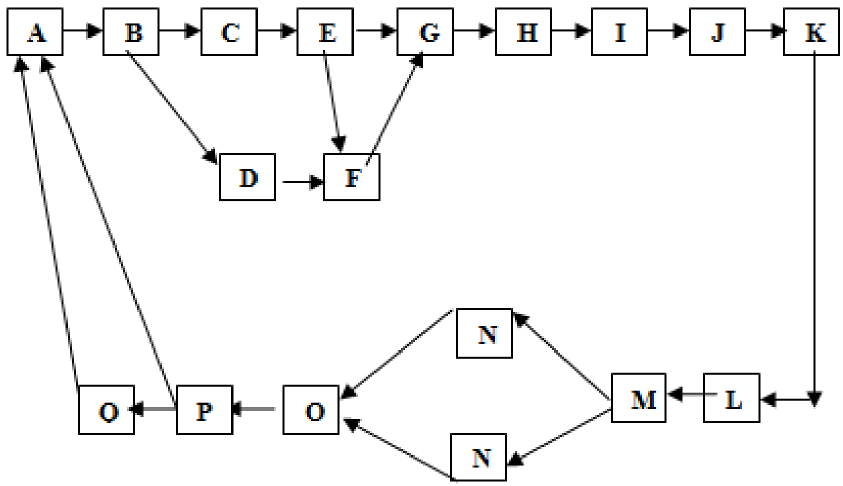

Fig. 1: Sequence of Operations in Existing Plant Layout.

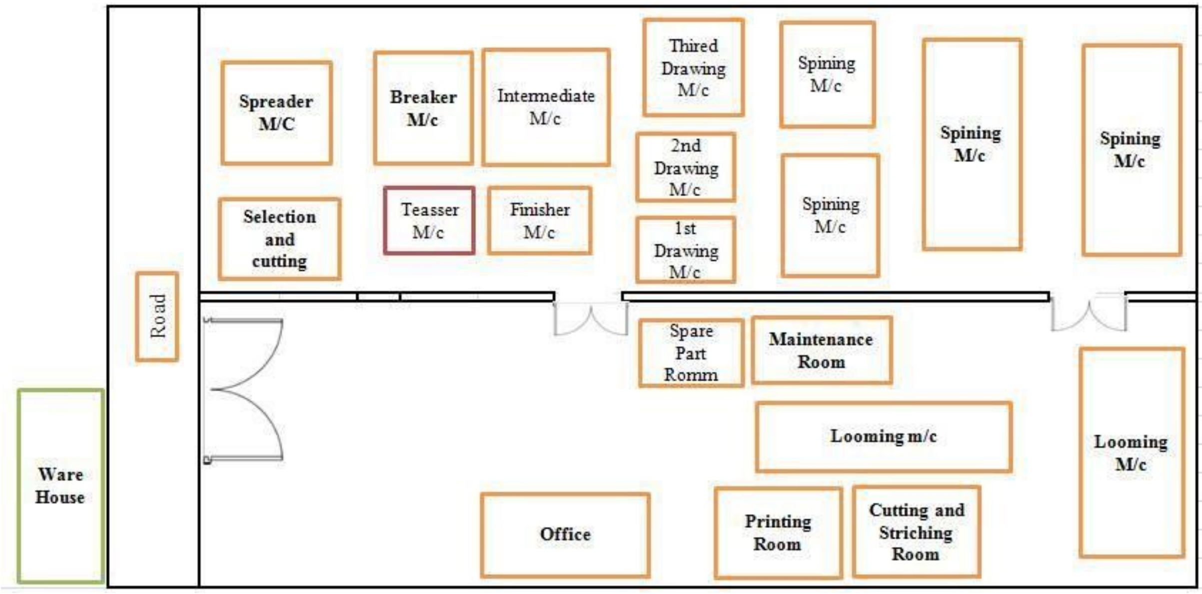

Fig. 2: Existing Plant Layout

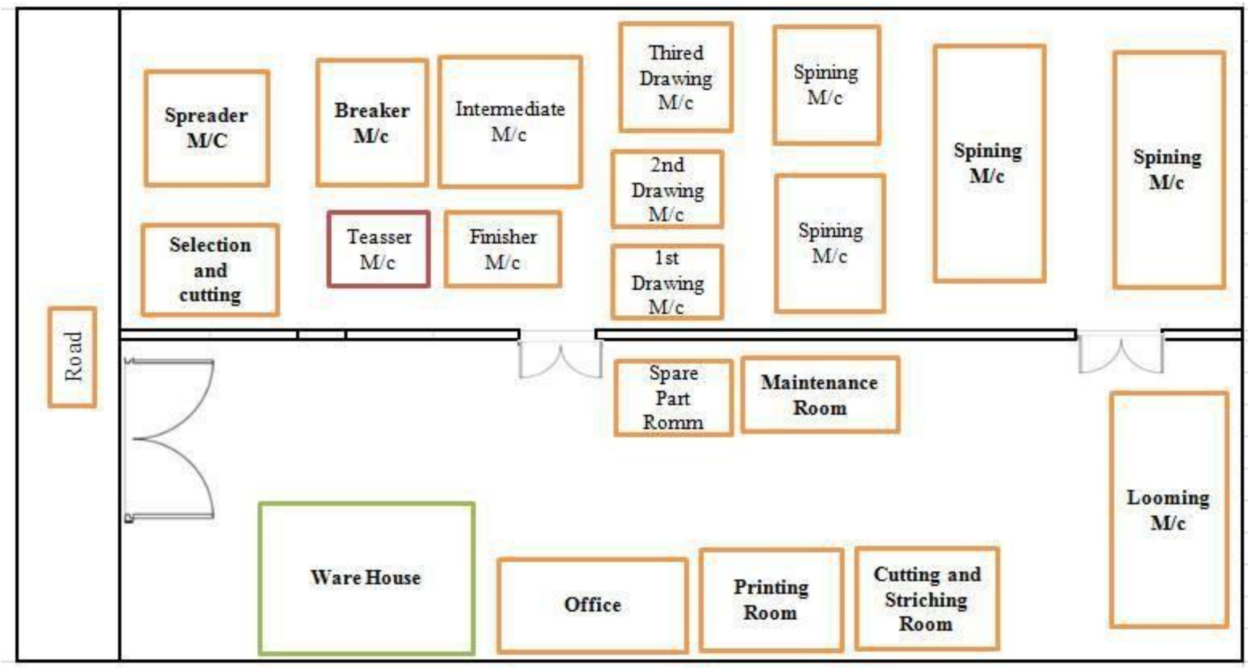

Fig. 3: Proposed Plant Layout

4: CONCLUSION AND RECOMMENDATIONS

In conclusion, layout redesign and lean methods resulted in significant reduction of the following indicators: amount of total workflow, material handling cost, total travel distance of goods, space used for assembly, number of workers, labour cost of workers and the number of stops. It has become very essential to have a well-organized plant layout, for all available resources in an optimum manner to achieve the maximum returns.

We recommended that material supply should be optimum to avoid "stock outs" while work in process, organizations should strictly adhere to management policy on facility layout and computerize their material management system in line with global changes for ease to track the movement of materials in the store.

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